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ScienceDirect

Procedia Engineering 147 (2016) 781 – 786

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Biofeedback system for novice snowboarding

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Abstract

The purpose of this project was to design a biofeedback system for beginner snowboarders. The aim was to design and build an electronic system, which analysed the load under the feet of the snowboarder and alerted the rider when more load was put on the back boot compared to the front boot. There are several stages involved in such a project including initial design phase, development of sensors, software development and testing of the product. This report details the design and fabrication processes involved in the project from initial design to working prototype. We were able to successfully design a biofeedback system for beginner snowboarders as well as test the system on the snow.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: snowboard; beginner; real-time biofeedback; load distribution; training enhancement

1. Introduction

The sport of snowboarding is one of the fastest growing sports in the world, with an estimated 9.8 million users on the slopes worldwide [1]. This is an increase of 280% in the number of snowboarders hitting the slopes since the year 2000 [2]. Consequently the sport of snowboarding has a high number of beginner participants (44 %) and first time participants (14 %) on the slopes each year [2]. Compared with other sports, especially with the more traditional snow sport of skiing, snowboarding has a short history [3]. However, with the short development span of the sport and huge growth in the industry, there is a unique opportunity for development and innovation in the manufacturing and design of not only snowboards, but all equipment involved in the sport.

There are different disciplines in snowboarding such as Halfpipe, Slopestyle, Freeride, just to name a few. However the scope of this study is only to focus on the basics of novice snowboarding. It is safe to state that turning is an essential skill to master for every beginner snowboarder. It can be seen as the foundation of further evolution and was therefore selected to be the subject of this study.

Beginner snowboarders use a rotational movement as a turning mechanism to perform an edge change. Rotation means the rotational movement of the whole body in monoblock in the direction of the turn [4]. The head is leading the movement, supported by a simultaneous use of shoulders and hips. The rotational movement in monoblock is supported by a slight inclination towards the inside of the curve, shifting the center of gravity, so that the board loosens the edge. It is carried out during the initiation of the turn to steer the board into the slope line. While performing the turn, there is a shift of weight expected to the front boot which will make it easier to steer into the slope line. In doing so, the rider releases the load on his back boot resulting in the ability to steer the rotation throughout the whole exit of the turn. One of the most common beginner mistakes is the ‘defensive’ stance on the board, meaning to shift the majority of the weight to the back boot.

Feedback provided by instructors is, as in many sports, a perception of what they see. It is subjective as it relies heavily on the skill level of the instructor to distinguish mistakes as well as their ability to accurately portray to the athletes what they have seen. It is essential for beginners to receive feedback when developing a new motor skill, such as making a turn in snowboarding [5].

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1877-7058
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.318

When teaching a new skill, the trainer generally gives performance feedback before commencing the activity, as well as delayed feedback after the execution of the skill. It is neither practical nor possible to give real-time feedback.

The use of a sensor system to provide real-time biofeedback would eliminate the disadvantages associated with the current method utilised by instructors. Biofeedback is a process of gaining a greater awareness of physiological functions through the use of instruments and sensors. It can provide the user with feedback through the 5 sensory areas of the body: sight, sound, touch, smell and taste [6]. In the sporting application however it is not practical to provide smell or taste feedback and thus the use of touch, sound and sight feedback mechanisms are often used [7].

It can be seen that the development of a real-time biofeedback feedback system to coach beginner snowboard athletes would greatly improve the development of motor skills. By adding, whether or not real-time, objective feedback on top of the subjective feedback from the trainer, the overall picture of the learning process will improve tremendously.

The objective of this study is to develop a functioning biofeedback system to assist beginner snowboarders with real time feedback of their weight distribution when performing turns. The scope of this study encompasses:

- fabrication of sensors for snowboard boots;
- development of a circuitry to connect sensors to Arduino;
- programming the Arduino to produce a biofeedback signal when set conditions are met;
- selection and development of a biofeedback mechanism;
- development of a Bluetooth system for wirelessly recording data;
- performing laboratory and on snow testing of the final system.

2. Biofeedback methods in snowboarding and skiing

The field of electronics has been significantly impacted in the last recent years due to the miniaturization of many components such as sensors, microcontrollers and computer devices [8]. This has opened up many research opportunities in various fields [9]. The development of open source electronics also plays a key role as hobbyists can build circuits and full operating systems from home. The sports and leisure sector has significant opportunities for the development of electrical systems which analyses and provide feedback on various physical phenomena.

Several attempts have been undertaken to objectify feedback in the ski- and snowboard world. Baca et al. [10] claim that providing feedback is only a matter of making use of pervasive computing, ubiquitous computer systems in our environment, and to equip the athlete with the necessary tools to make use off. Harding et al. [11] however concluded that the integration of these automated objectivity systems is not an easy task. In practice the trainer still provides feedback before the run or after, during the debrief. Real time feedback is still hard to realise. In skiing Michalles et al [12] developed a wired system which collected data on the skier's movements on the slope. However, this system was not able to provide real-time feedback to the skier. Instead the data were recorded and later analysed. Moreover, little information is given on the type of sensors used in this project.

Kondo et al. [13], in their attempts to gather information about snowboard performance, utilized force sensors. Previously they conducted a similar research in the ski world with inertia sensors [14]. Hirose et al. [15] focused on the performance of dynamic motion analysis by measuring the reaction force of the snow. This study was a step in the right direction. However, the inclusion of real time feedback was still absent. As indicated in the study of Spelmezan et al. [16], there is great potential in teaching sport skills by means of real time feedback, specifically with implementation of tactile instructions.

Kirby [17] developed a ski speedometer (vLink™, Advanced Racing Computers, Salt Lake City UT, USA) based on ONT (optical navigation system), that feeds back the sideward displacement of the rear edge in an imperfect carving turn with a beeping sound. The athlete hears a Geiger counter-like beep for every 0.50mm of lateral displacement [17].

Our research is a combination of previous studies to develop a simple effective biofeedback system.

3. Development and method

3.1. Systems design

The system encompasses four pressure sensors (two per foot), the data of which are processed by a microcontroller and sent wirelessly to a smart phone (Fig. 1). The microcontroller also actuated a vibration device and an LED for feedback purposes. Additionally, camera footage (handheld and board-mounted) is sent to the smart phone as well.

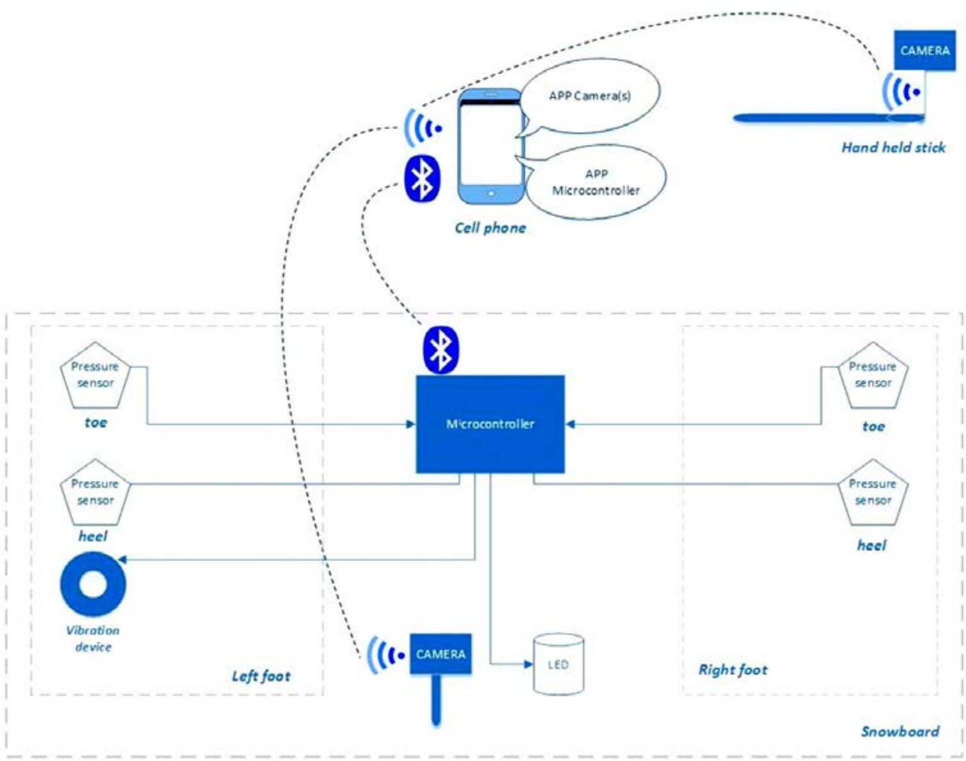

Fig. 1. Systems design.

3.2. Electronics

Four foot sensors were developed from a piezoresistive polymer (Rmat2a, RMIT materials code) and copper foil electrodes (Fig. 2a). The sensors were located at the heel and toes of both feet. They were connected via wires with plugs (Fig. 2b) to the microcontroller board, to allow for easy release when unclicking the boot from the electronics board.

The four sensors were connected independently to the analog inputs of the programmable microcontroller (Arduino Uno, Sparkfun Electronics, Niwot, Colorado, USA). Each sensor was connected in series with a 33 Ω reference resistor before connecting to ground. The change in drop voltage with pressure was measured across the reference resistor.

For the biofeedback signal two methods were used. An LED was connected to the microcontroller which allowed for external parties to view the snowboarder's weight distribution. However, for the (novice) riders themselves, it is not ideal to constantly monitor the LED on the snowboard. To compensate for this a vibration device was placed in the front boot. When the microcontroller determined that there was excessive weight on the back boot compared to the front boot, the vibration device and LED were activated to remind the rider to put more load on the front boot. A graphical representation of the final instrumentation design is shown in Fig. 2c.

The system was tested in the laboratory, by mimicking correct (load on front boot) and incorrect (load on rear boot), as well as marginally correct and incorrect, load distributions to ensure that the voltage signal accurately reflected the load conditions.

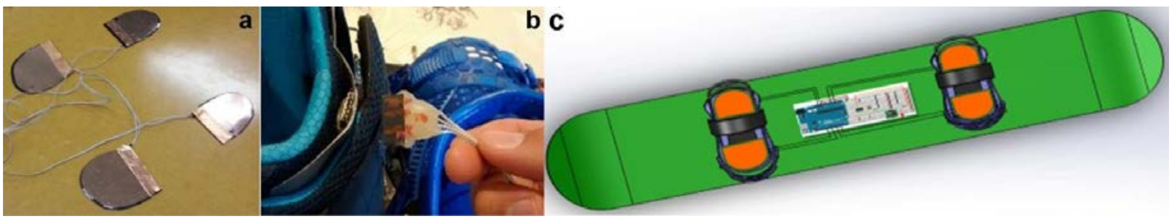

Fig. 2. Sensors (a), connectors (b) and final instrumentation design (c).

3.3. Programming and data processing

An Arduino Uno was used as the main microcontroller. The Arduino Uno also has TXD (transmit data) and RXD (receive data) pins which allows Bluetooth integration. The programming code was written using the Arduino IDE (Integrated Development Environment) software. The key parts of the code included: initialization of the variables; initialization of inputs/outputs and their current state; integration of Bluetooth libraries; reading sensor values; turning on biofeedback when required.

One of the key issues involved in the programming of the sensors was determining when to turn on the biofeedback system. There are always instantaneous spikes of load which are not relevant for the purpose of the system. To ensure that the biofeedback signals did not switch on due to random load spikes, a two second sliding window was used. If the back boot had a greater proportion of the load during this period the biofeedback signals were turned on, until the load distribution was corrected.

A wireless Bluetooth (BT) module, Sparkfun Bluesmirf Silver (SparkFun Electronics, Niwot, Colorado, USA) module was connected to the Arduino Uno. The Bluesmirf device communicated wirelessly with a HTC (High Tech Computer Corporation, Taiwan) phone to transmit the sensor data at 20 Hz sampling rate frequency. The Bluesmirf used a software serial port to communicate with the HTC phone, using an app called 'BlueTerm2'. This app was sourced from the Google Play Store. The app allowed for the data to be saved onto the SD card of the phone, so that it could be used for post processing.

3.4. Experimental procedure

The system developed is a prototype. For the on snow and laboratory testing of this prototype, the microcontroller, circuitry and battery were placed in a clear waterproof container. The container was packed with foam to ensure the microcontroller and batteries were insulated and would not move during testing. After which it was attached directly to the snowboard. The sensors were placed inside each snowboard boot and an insole was placed over the top to hold them in place. The connectors for each boot were fastened at the top of each boot to allow for the sensors to be disconnected from the boot at the base of each run. Two GoPro® cameras were used to film two different perspectives. The first camera was connected directly to the snowboard to monitor the states of the LED. The second camera was mounted on a hand-held stick and held by the tester perpendicular to the frontal plane. This view recorded the perceived weight distribution of the participant throughout different turns via the knee flexion angle and relative body position. This is a common view which would be used by an instructor in the current technique to provide objective feedback.

All tests were conducted on Mount Buller, Victoria, Australia. Three principle runs with three turns each were performed. With the same order, the turns were as follows:

- Turn 1- Execution of turn with the correct technique. In this turn all the weight was placed on the front boot, no biofeedback signal should be activated during this turn;
- Turn 2 - Execution of turn with amended technique. In this turn the weight was on the front boot at the start of the turn. When initiating the turn the weight was shifted to the back boot which triggered the biofeedback signal (this is a common problem amongst beginner snowboarders);
- Turn 3 - Execution of turn with incorrect technique. For this style of turning the weight was predominately located on the back boot throughout the whole turn. The biofeedback mechanisms are active throughout the entire duration of the turn. (Usually, novices would not be able to complete the turn, but this was executed to demonstrate the biofeedback signal was going to be active throughout the whole phase).
- Note that each turn was done in a backside turn, from toe edge to heel edge, as well as a frontside turn, from heel edge to toe edge.

All tests were conducted with a regular stance left hand dominant participant. Therefore, for all tests, the rear boot is attached to the right leg and the front boot to the left leg. A HTC phone was used in conjunction with the GoPro® cameras to record all sensor data at 20 Hz for each run. The final test setup shown in Fig. 3.

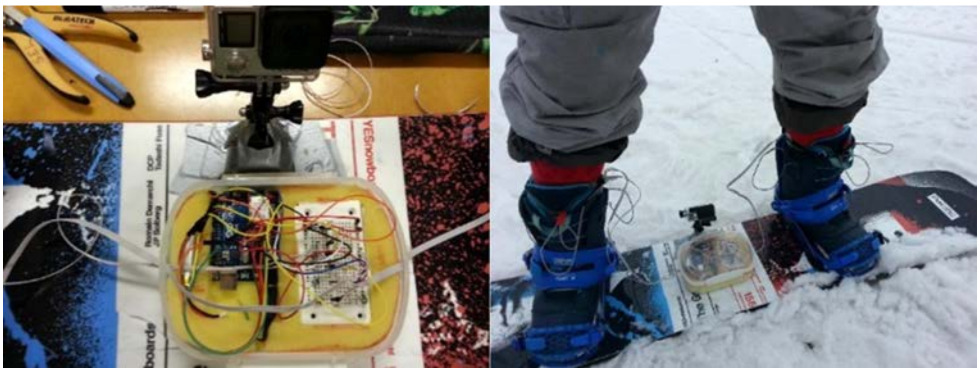

Fig. 3. Testing container with padding, microcontroller, circuit and Go Pro ® camera (left); test set-up on the slope (right)

4. Results

Fig. 4a shows the sum of the values of the front boot as well as of the back boot. Fig. 4b shows the four individual sensors of toe and heel of front boot, and toe and heel of back boot separately. The load is given as relative values, normalized to the measured peak load (right or left boot, wherever the maximum load was located; the reason for displaying the relative load is that the sensors did not cover the entire foot/boot area. The maximum load was taken, irrespective whether it was on the front or back boot, and set it to 100%.

All the different colored boxes combine the data of one backside turn and a frontside turn conducted consecutively.

- Green box: Correct technique turn: the weight is concentrated on the front toe and heel sensor.
- Yellow box: Amended turn: showing that the participant is starting off on his front boot but during initiation of the turn, shifts his weight to the back boot in both turns.
- Red box: Incorrect technique turn: the weight is distributed to the rear foot throughout both turns.

Several runs were conducted with similar results. This reveals the consistency of both the overall system and the participant on the day.

5. Discussion

We were able to successfully fabricate functioning sensors inside a snowboard boot and develop circuitry connecting the sensors to an Arduino microcontroller, which was then programmed to produce a biofeedback signal when a set condition was met. A biofeedback system was developed which allowed both the user and third party to be alerted when the incorrect technique of weight distribution was executed. The system was always active, not only during turns for improving turning technique purposes. Performing turns is the most important skill to gain for novice snowboarders and therefore the most commonly practiced. Nonetheless, providing the feedback was useful for global analysis of the riders performance because an optimal posture is required during snowboarding and not only when making turns. The team also incorporated a Bluetooth system into the circuit which allowed for data recording and sets up possibilities for further work on the project at a future date. The whole system was successfully tested in both a laboratory and on the slope.

The final system was waterproof with the use of a clear container taped to a snowboard. With this set up the rider conducted three runs on a beginner level slope on Mount Buller. The participant undertook three types of turns for each run. This was successfully seen on the day with the biofeedback systems activated when the participant's weight was distributed towards the rear of the board. The activation of the biofeedback system was also recorded on the camera footage of the two GoPros® and by the data transmitted to the HTC phone over a Bluetooth connection with the microcontroller.

6. Conclusions

A biofeedback system was developed which allowed both the user, novice snowboarder, and third party to be alerted when the incorrect technique of weight distribution was executed. The whole system was successfully tested in both a laboratory and on the slope.

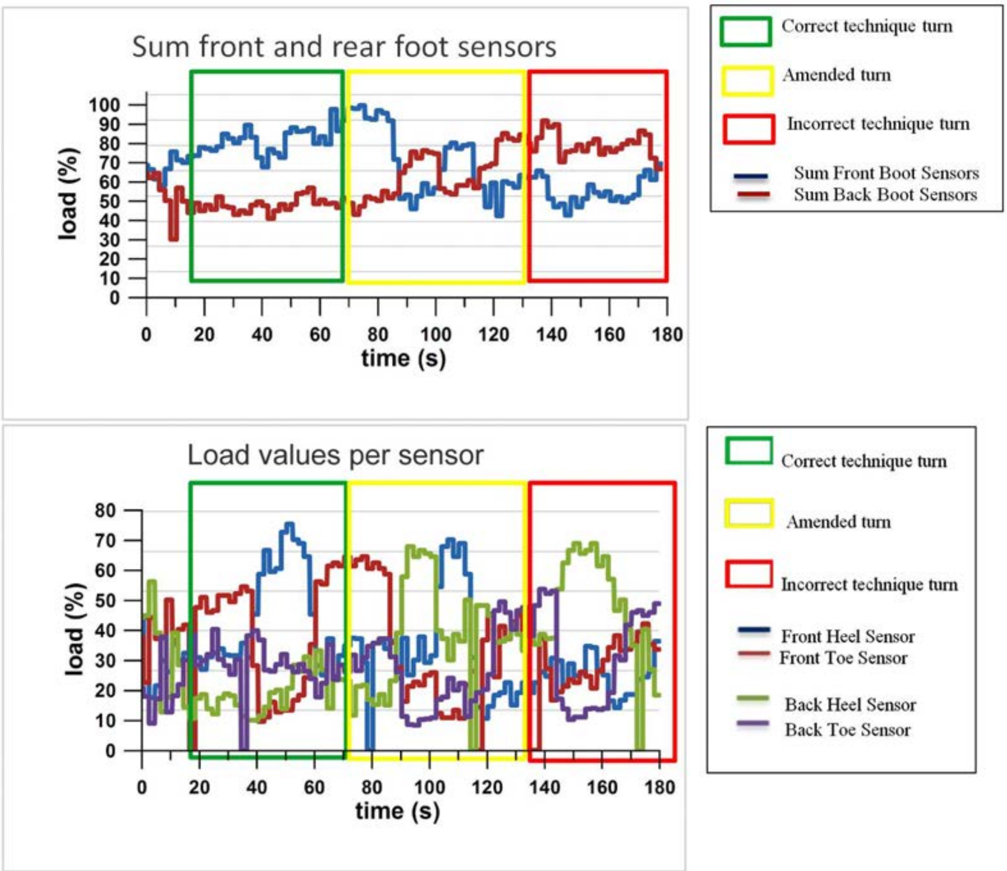

Fig. 4. (a) Sum of load of front and back boot sensors and (b) load values per sensor against time (the load is given as relative values, normalized to the measured peak load (right or left boot, wherever the maximum load was located; the reason for displaying the relative load is that the sensors did not cover the entire foot/boot area).

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